BNL Nuclear Theory Group

DOE S&T review, June 27-29, 2011

Group Mission

- **Excellence** in scientific research aimed towards accomplishing goals set by BNL and DOE Office of Science
- **Support and guidance** for experimental programs at RHIC & elsewhere
- **Training** a new generation of nuclear theorists
- **Chart the course for future** directions in Nuclear Physics

Physics program of BNL Nuclear Theory Group

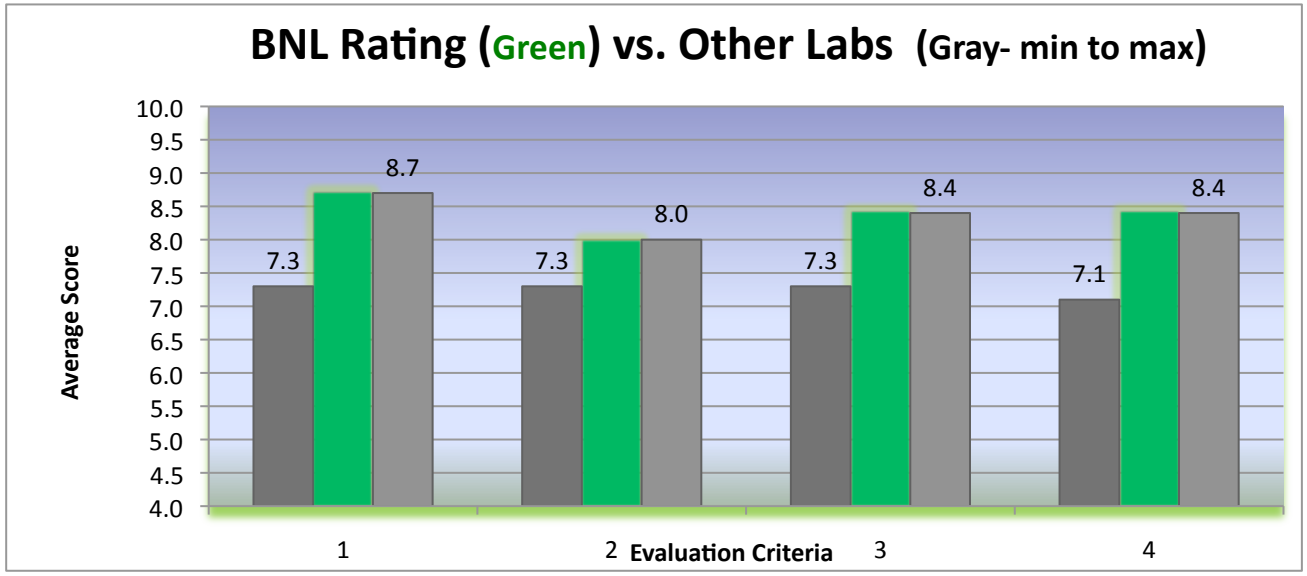
- Quantum Chromodynamics at finite temperature and baryon density and the physics of the Quark-Gluon Plasma
- QCD at high energies (small x) and the physics of saturation -Color Glass Condensate
- Perturbative QCD and hadron structure-in particular, the spin of the proton
- Electromagnetic interactions of nuclei at high energies and nuclear structure

All these topics are tightly connected to existing and planned experimental programs at BNL

DOE review, Sept. 2009

- **Joint four year review of Nuclear Theory Groups at all National Labs**

- ***BNL NT Group rated highest in all evaluation criteria by all reviewers***



1) Quality of Group's scientific & techincal accomplishments

2) Merit, feasibility and potential impact of proposed research

3) Contribution of past and proposed research to national theory effort

4) Cost-effectiveness of requested funding including any funding from the lab

Staff of the Nuclear Theory Group

Group Administrator:

Marcy Chaloupka

Long term Scientific Staff:

A. Baltz
D. Kharzeev[1]
J. Millener
L. McLerran
R. Pisarski
J. Qiu[2]
M. Stratmann[3]
R. Venugopalan (Group Leader[4])

Post-doctoral Fellows:

G. Beuf[a]
D. Fernandez-Fraile[b] (Fulbright)
J. Liao[c]
B. Schenke (LDRD)

a – from 10/1, post-doc at Santiago de Compostela, Spain
b - from 10/1, Humboldt Fellow, Frankfurt U.
c – from 8/1, joint Indiana Univ./ RIKEN-BNL junior faculty position

1 – former Group Leader, joint with Stony Brook from 6/1/2010
2 - from January 2010, hired in search to replace W. Vogelsang
3 - from October 2010, joint with Aschenauer's Group
4 – from June 2010

Recent departures and anticipated arrivals

Recent post-doctoral fellows:

Kevin Dusling, now post-doc at NC State

Maxim Khodas, junior faculty at Univ. of Iowa

G. Soyez, CNRS, permanent position at Saclay, France

Recent staff departure:

W. Vogelsang, full professor (W3) at Univ. of Tübingen, Germany

New post-doctoral hires:

V. Skokov, from GSI, Germany

Y-Q. Ma, Peking University (LDRD)

NT post-docs (99'-present) in permanent positions

i) Y. Kovchegov (Ohio State, OJI, Sackler Prize)
ii) F. Gelis (CEA, Saclay, France)
iii) A. Peshier (Professor, Univ. of Cape Town, SA)
iv) A. Dumitru (tenure track, RBRC Fellow at Baruch College, CUNY)
v) J. Wirstam (Staff Scientist, Defence Research Agency, Sweden)
vi) T. Fugleberg(Professor and Chair, Brandon Univ., Canada)
vii) E. Fraga (Associate Professor, Federal University, Rio de Janeiro, Brazil)
viii) J. Jalilian Marian, (Baruch College, CUNY)
ix) D. Teaney (tenure track, Stony Brook, OJI, Sloan)
x) K. Tuchin (Iowa State U)
xi) A. Stasto (tenure track, RBRC fellow at Penn. State, OJI, Sloan)
xii) G. Soyez (CNRS, Saclay, France)
xiii) M. Khodas (tenure track, Univ. of Iowa)
xiv) J. Liao (tenure track, RBRC fellow at Indiana Univ.)

Students mentored: 2001-2011

J. Bjoraker, Y. Hatta, B. Jaeger, J. Lenaghan, R. Parwani,
V. Peikert, J. Wirstam, H. Yokoya, E. Megias, D. Fernandez-Fraile,
B. Wu, L. Almeida, Shu Lin, S. Mohapatra, S.Srednyak,
Ricardo Andres Torres, Hong Zhang, Tyler Corbett, P. Tribedy

Supervised by D. Kharzeev, R. Pisarski, J. Qiu,
R. Venugopalan, W. Vogelsang

D. Kharzeev: Joint faculty position at Stony Brook
J. Qiu: Adjunct Professor at Stony Brook (Brookhaven Professor at YITP)
R. Venugopalan: Adjunct Professor at Stony Brook

Publications and citations

Name	Career (ref.journals) publications	Career (ref. journals) citations	Publications (ref. journals) 2008-present	Citations (ref. journals) 2008-present
Baltz	63	1602	5	123
Beuf	9	87	8	75
F-Fraile	11	120	6	70
Kharzeev	125	6615	26	1062
Liao	19	384	14	178
McLerran	164	15189	19	681
Millener	67	1613	7	44
Pisarski	100	10,422	12	201
Qiu	98	6592	15	189
Schenke	18	260	11	150
Stratmann	50	2631	7	149
Venugopalan	92	7311	21	676

INSPIRE search 06/25/2011, refereed publications and recent preprints only

Awards and Honors (2009-present)

A.J. Baltz: APS Fellow (2010)

D. Kharzeev: AAAS Fellow (2011)

L. McLerran: Hans Jensen Prize and Chair, Univ. of Heidelburg (2009-present)
Liu Lianshou Chair, Central China Normal Univ. (2011)
Honorary Ph.D from the People's Republic of China (2011)

J. Qiu: Brookhaven Professor (Adj.) at Stony Brook Univ.

R. Venugopalan: International Scientific Associate, Discovery Center,
NBI, Copenhagen (2010-present)
Chair, Brookhaven Council (2010-2011)

Nuclear Theory Group at BNL

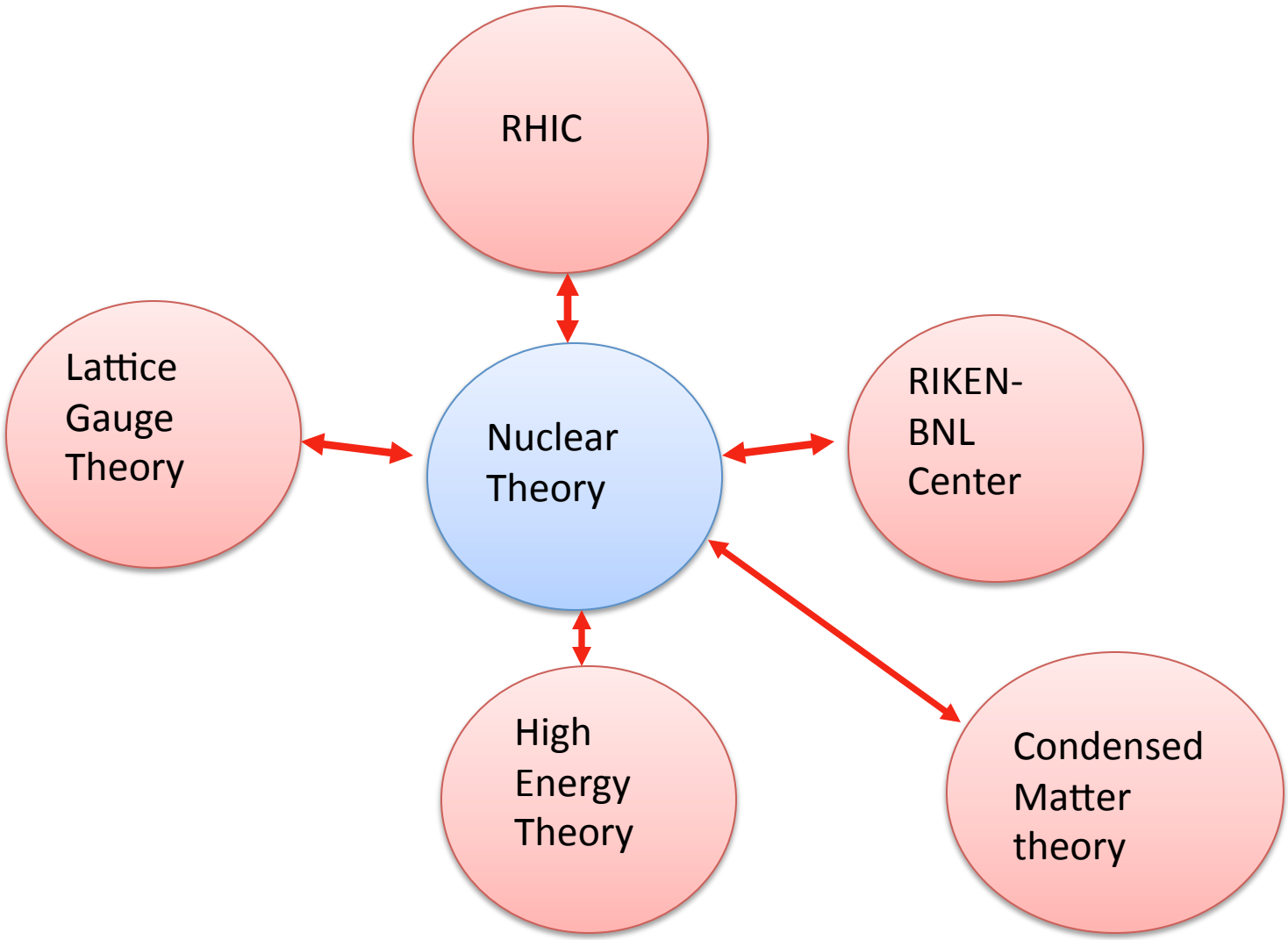


Table 4: Milestone Progress in Hadronic Physics

Year	Milestone	Complete?	Status Assessment
2008 HP1	Make measurements of spin carried by the glue in the proton with polarized proton-proton collisions at center of mass energy, $\sqrt{s}$ = 200 GeV.	Yes	Achieved

Table 11: New, Updated and Continuing Milestones for Hadronic Physics

2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12 (update of HP1)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering

Table 12: New, Updated and Continuing Milestones for High Temperature/High Density Hadronic Matter

Year	#	Milestone
2009	DM4	Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.
2010	DM5	Measure the energy and system size dependence of J/Ψ production over the range of ions and energies available at RHIC.
2010	DM6	Measure e^+e^- production in the mass range $500 \leq m_{e^+e^-} \leq 1000$ MeV/c^2 in $\sqrt{s_{NN}} = 200$ GeV collisions.
2010	DM7	Complete realistic calculations of jet production in a high density medium for comparison with experiment.
2012	DM8	Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions.
2014	DM9 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
2014	DM10 (new)	Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies from medium RHIC energies to the highest achievable energies at LHC.
2015	DM11 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ between 5 and 60 GeV to search for evidence of a critical point in the QCD matter phase diagram.
2016	DM12 (new)	Measure production rates, high p_T spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}} = 200$ GeV.

Nuclear Theory @ BNL and the physics of RHIC

Lattice Gauge Theory:
Equation of state, fluctuations,
Transport coefficients, …
Karsch, Petreczky, Mukherjee,,…

Initial conditions, QCD at small x

Kharzeev, McLerran, Venugopalan, Qiu, **Dusling, Schenke, Beuf, F-Fraile, Soyez**

Pre-equlibrium dynamics:
Long-range rapidity correlations,
Local strong parity violation, …

Dusling, Liao, Kharzeev, McLerran, Venugopalan, Schenke, Beuf

Transport coefficients, viscous hydro & properties of sQGP
Kharzeev, Pisarski, McLerran, Venugopalan; Dusling, Schenke, Liao, F-Fraile

EIC

QCD critical point
McLerran,
Pisarski
Kharzeev

Perturbative QCD and spin physics

Stratmann, Qiu

Hard probes of QGP: jets, heavy quarks, dileptons, …
Kharzeev, **Liao, Dusling, Schenke, Soyez,** Venugopalan, Qiu

Electromagnetic processes at high energies, ultra-peripheral collisions, (hyper)nuclear structure

Baltz, Millener

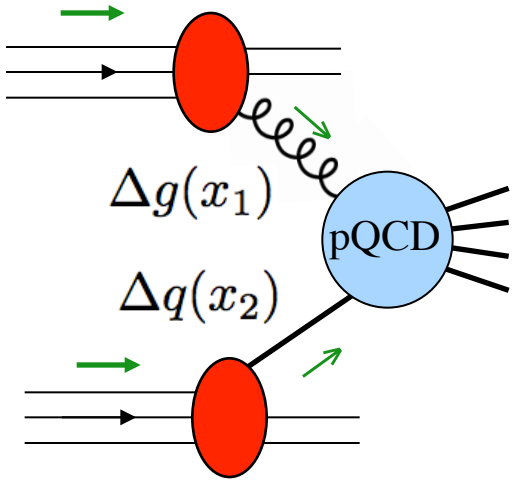
Key work from Group members and post-docs driving BNL/RHIC program*

i) Color Glass Condensate Theory / Phenomenology (1053 / 437)
ii) Forward d+A program (232)
iii) Glasma / Glasma Flux tubes/simulations/ (173/125/232)
iv) Chiral Magnetic Effect (195)
v) Quarkyonic Matter (206)
vi) Viscous Hydro (419)
vii) Successful Jet finding algorithms (214)
viii) NLO pQCD for benchmark p+p calculations (184)
ix) Global spin analysis (416)
x) Dead Cone Effect / Novel Theory of Quarkonium production (313/?)
xi) Invention of HTL finite temperature field theory / Polyakov look model of QCD physics at T_c (931/194)
xii) eRHIC (89)

* Citations of most cited paper in area to indicate impact of contributions

Major objectives of RHIC Spin program

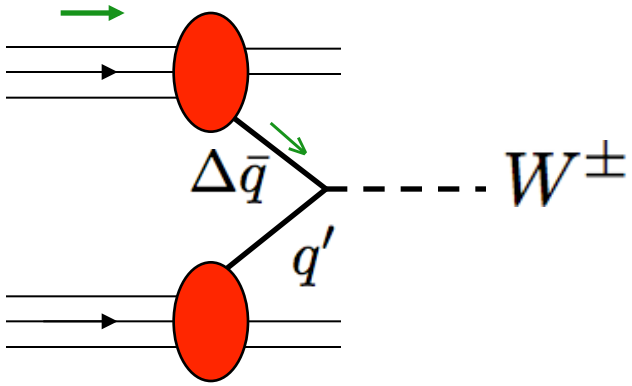
- **gluon contribution to proton spin:**



$$\Delta g(x) = \quad - \quad$$

$$\Delta G = \int_0^1 dx\, \Delta g(x)$$

- **new probes of quark and anti-quark polarizations:**



- ***transverse*** **spin effects in pp at high energies**

I. RHIC spin and pQCD

BNL Nuclear Theory has a significant focus on hadron structure at high energies: especially nucleon spin, parton distribution functions, fragmentation functions, conceptual and technical problems in perturbative QCD dynamics

Strong integrated effort with the RHIC spin program:
Higher order computations, phenomenological models, global analyses, guidance for experiments

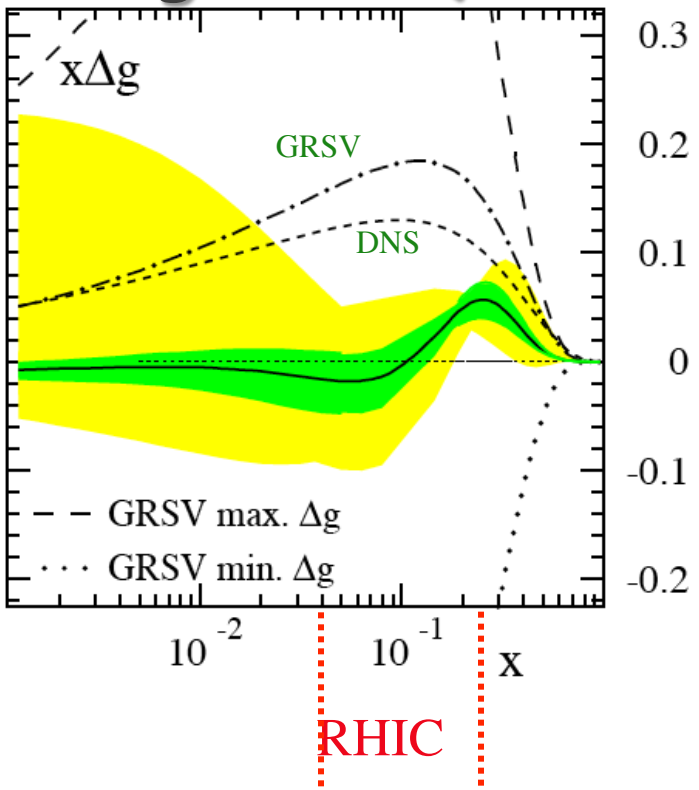
Recent key publications:

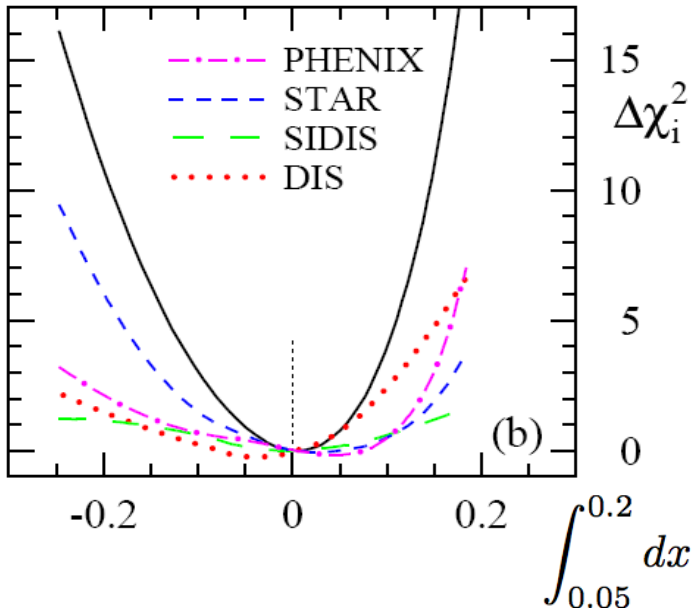
i) Z-B. Kang and J-W. Qiu, Phys. Rev. D81 (2010) 114030
ii) Z-B. Kang and J-W. Qiu, Phys. Rev. D83 (2011 094011
iii) J-W. Qiu, Prog. Theo. Phys. Suppl. 187 (2011) 210.
iv) J. Riedl, A. Schafer, M. Stratmann, Phys. Rev. D80 (2009) 114020
v) R. Sassot, P. Zurita, M. Stratmann, Phys. Rev. D81 (2010) 054001
vi) C. Aidala, F. Ellinghaus, R. Sassot, M. Stratmann, Phys. Rev. D83 (2011) 034002

Effort also very relevant and useful for experiments at Jlab and LHC

R. Sassot, P. Zurita, M. Stratmann, Phys. Rev. D82 (2010) 074011 (NLO analysis of pp hadron spectrum at LHC)

global QCD analysis of polarized PDFs





$$\int_{0.05}^{0.2} dx\,\Delta g = 0.006 \pm 0.06 \qquad (\Delta\chi^2 = 1)$$

$$\int_{0}^{1} dx\,\Delta g = -0.084 \pm ?$$

de Florian, Sassot, Stratmann, Vogelsang (DSSV), PRL101 (2008) 072001

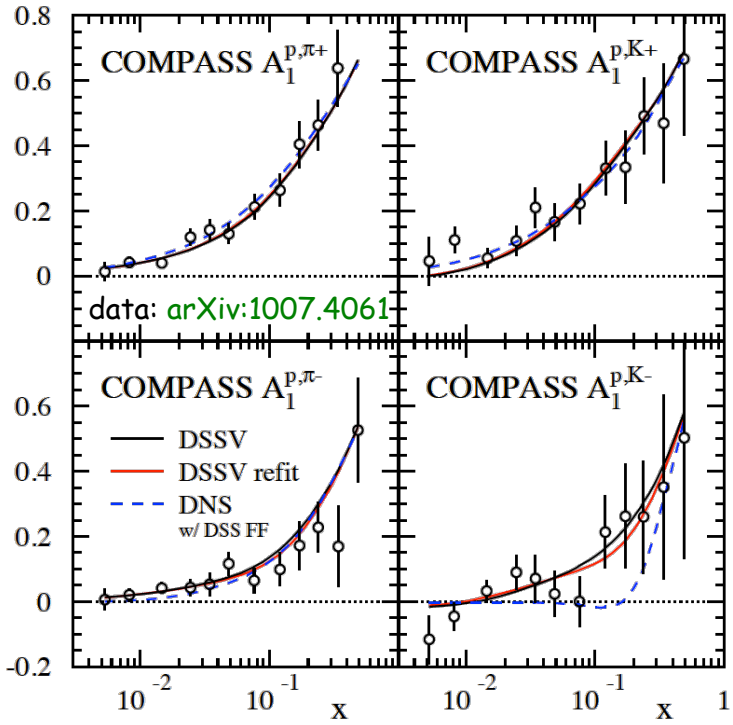
HP12

- **there could still be significant contribution to the integral from the unmeasured small x region – order 1 contribution to proton**

global QCD analysis of polarized PDFs

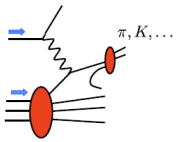
de Florian, Sassot, Stratmann, Vogelsang, PRL101 (2008) 072001, PRD80 (2009) 034030

continuous effort to improve QCD fits / incorporate new data



impact of recent semi-incl. DIS data

Stratmann @ DIS 2011

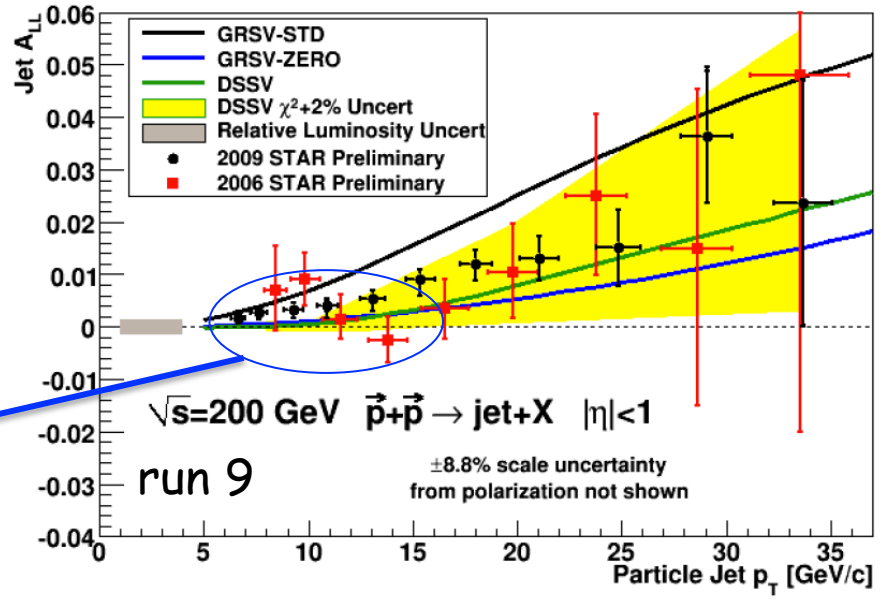


- well compatible with DSSV analysis
  --> not necessary to release refit
- some trend for less net polarization of sea
  e.g., $\Delta\bar{u} - \Delta\bar{d} \neq 0$ less significant

latest (prel.) STAR/PHENIX data for A_{LL}

expect: (work in progress)

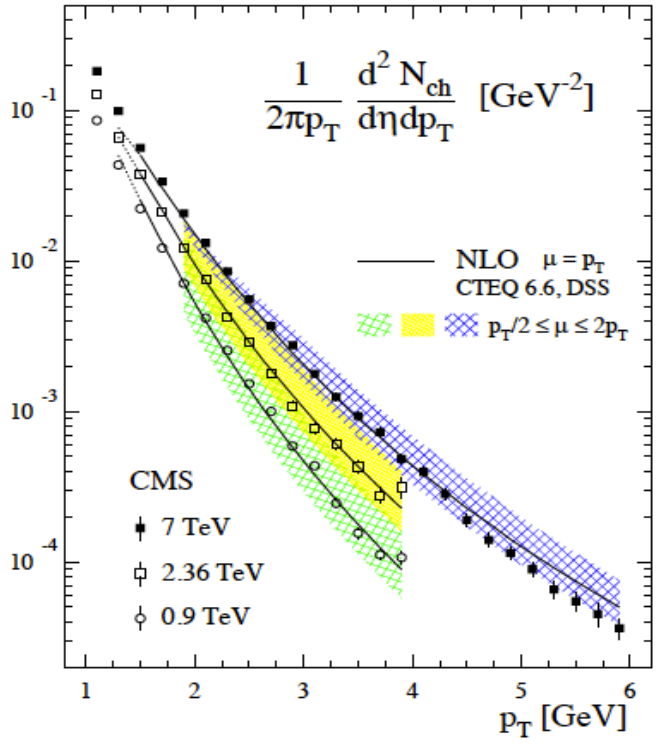
- slightly larger gluon polarization
  compared to DSSV analysis
- node in Δg might go away (?)



Suite of fragmentation functions

DSS FFs for $\pi^{\pm}$, $K^{\pm}$, … now challenged also at the LHC

Sassot, Stratmann, Zurita
PRD82 (2010) 074011

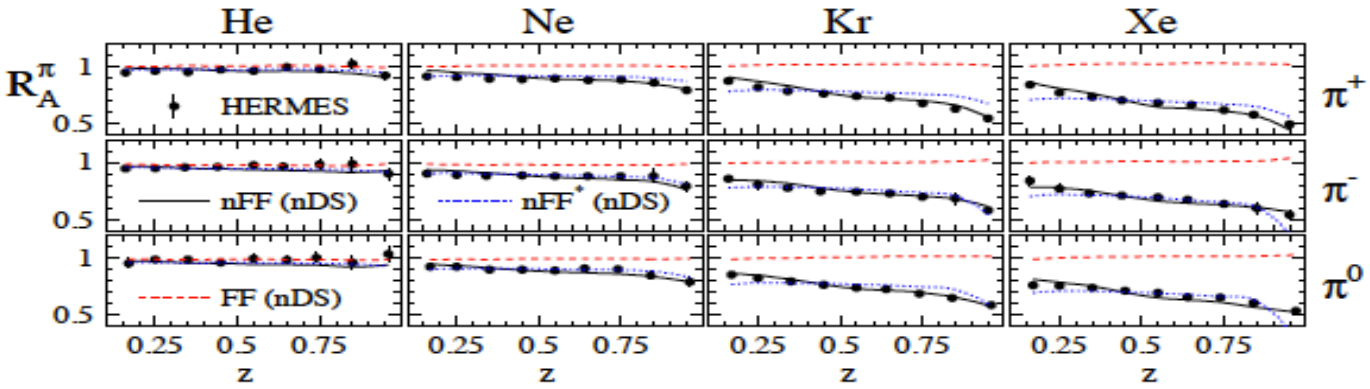


- works very well so far (ATLAS, CMS, ALICE data)
- new data will be used in upcoming update of DSS
- also new hadron yields from RHIC experiments

quantifying medium modifications in eA, pA

Sassot, Stratmann, Zurita, PRD81 (2010) 054001

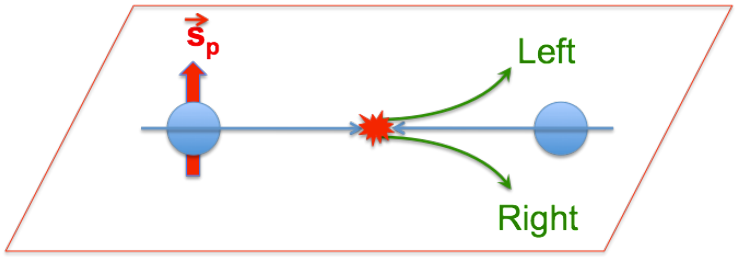
- find limits of collinear/DGLAP framework
  works well with current data, must break down eventually
- A dependence based on simple ansatz
  requires only very few parameters
- find $D_{q/A}$ suppressed, $D_{g/A}$ enhanced around z≈0.5

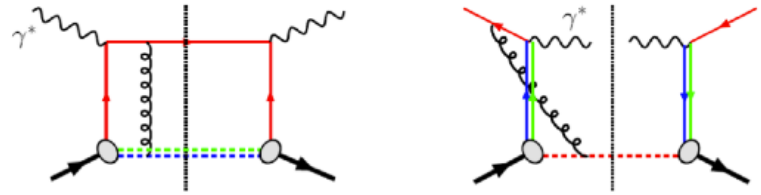


example:
pion attenuation in eA
fit vs HERMES data

Single transverse spin asymmetries & Sivers effect

- Single transverse spin asymmetry is a left-right asymmetry
- Sivers effect has been proposed as one of the important contributions
- Sivers function depends on the interaction between the active parton and the remnant
- Final-state interaction in SIDIS and initial-state interaction in DY makes Sivers function opposite sign from DIS
- In pp, both FSI and ISI contribute. Use Sivers function extracted from SIDIS to predict asymmetry in pp

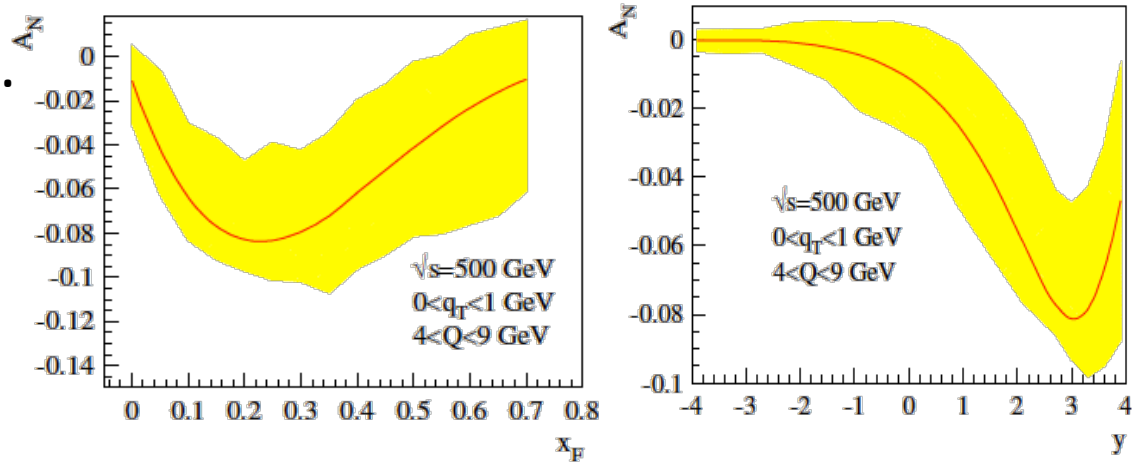




$$\Delta^N f_{q/h^\uparrow}^{\mathrm{SIDIS}}(x, k_\perp) = -\Delta^N f_{q/h^\uparrow}^{\mathrm{DY}}(x, k_\perp)$$

HP13 (new)

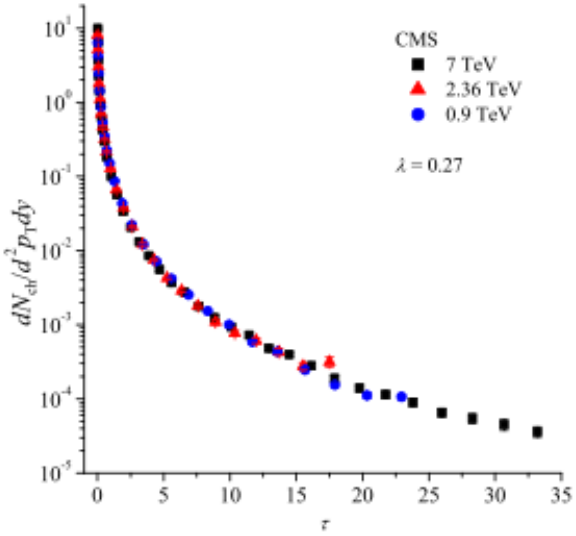
expectations for DY (Kang, Qiu)



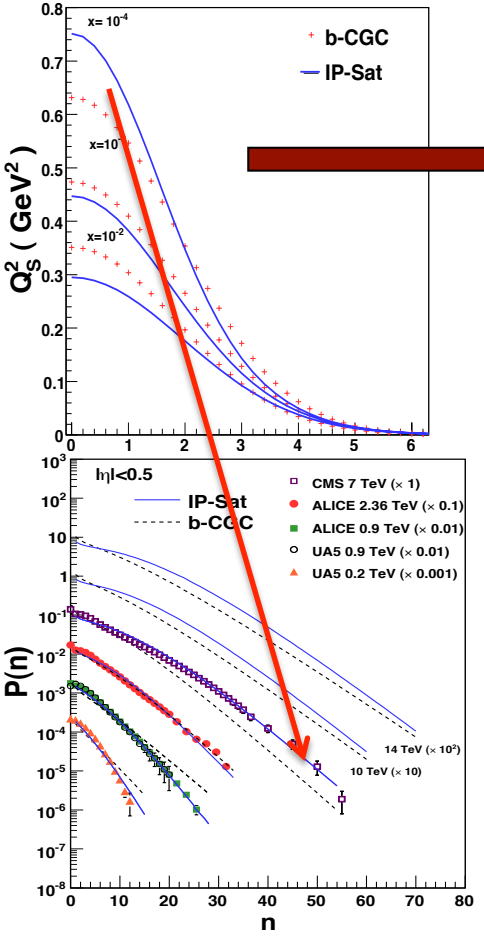
II. High parton densities & initial conditions in HI collisions: recent highlights

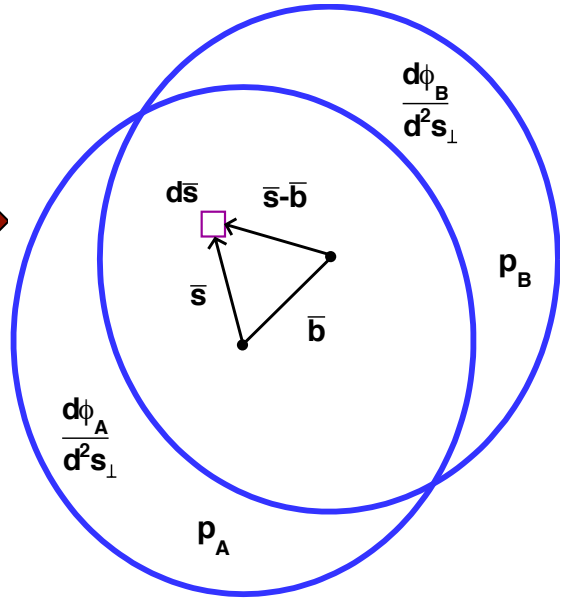
CGC & interesting features of p+p collisions @ the LHC

McLerran,Praszalowicz (2010-2011)



Scaling of inclusive hadron data with Qs





Tribedy & Venugopalan, NPA850 (2011) 136

DM8

Work influenced high multiplicity trigger analysis in current p+p 500 GeV run at RHIC

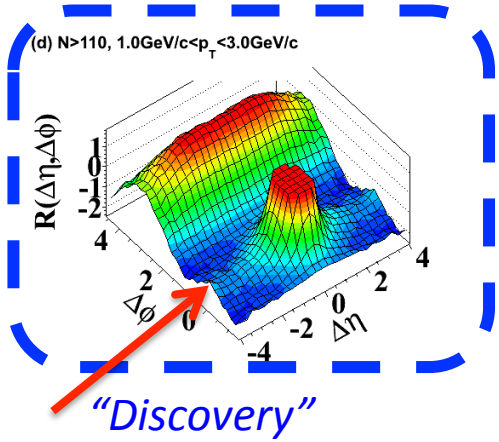
- **Important work by G. Beuf on next-leading-log evolution of Qs**

II. High parton densities & initial conditions in HI collisions: recent highlights

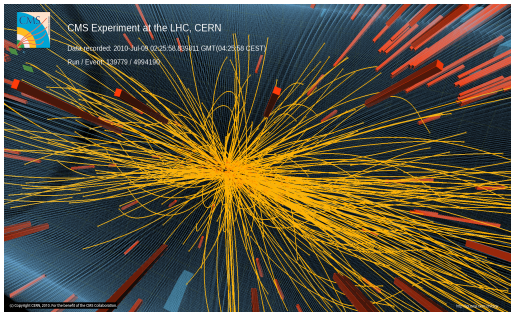
The p+p ridge @ the LHC

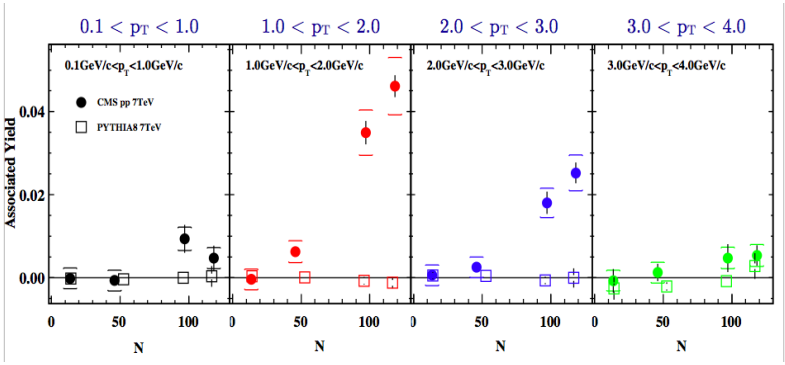
The high-energy collisions of protons in the LHC may be uncovering "a new deep internal structure of the initial protons," says Frank Wilczek of the Massachusetts Institute of Technology, winner of a Nobel Prize

Scientific American, February (2011)



"Discovery"

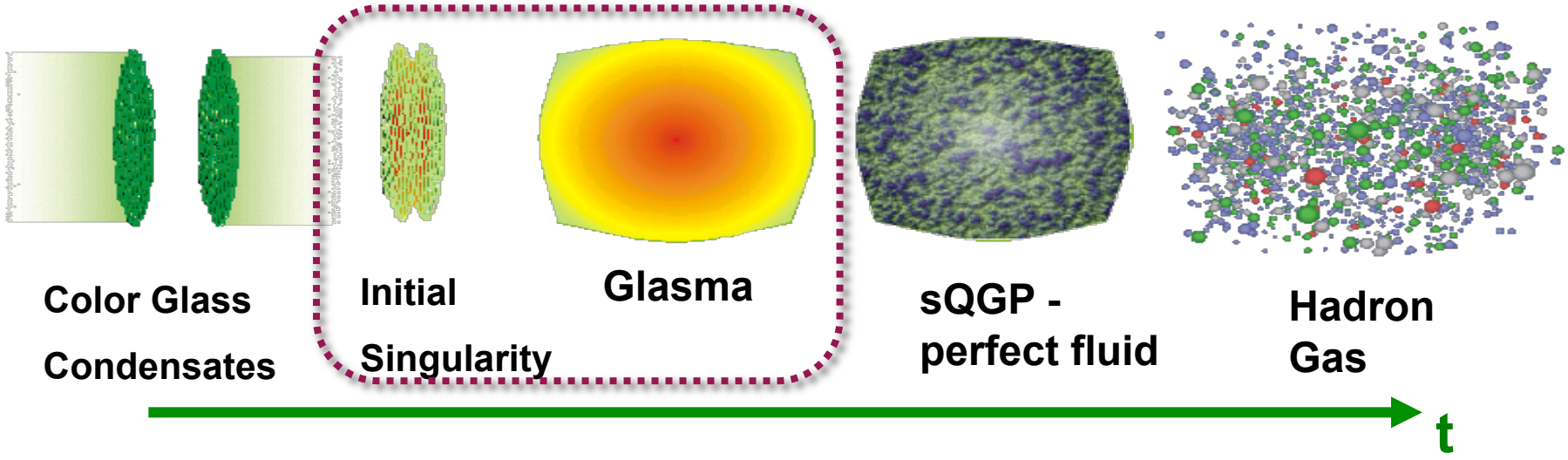




- ***Predicted*** **by A. Dumitru based on formalism in Dusling,Gelis, Lappi, Venugopalan (2010)**
- **Explanation of the effect (Dumitru,Dusling,Gelis,Jalilian-Marian,Lappi,Venugopalan,Phys. Lett. B697 (2011)21)**
- **Detailed comparison with data (Dusling, Venugopalan (2011) to be submitted to PRL)**

Work received wide attention worldwide in popular press (AP, Discover, Physics World,Ars Technica,..)

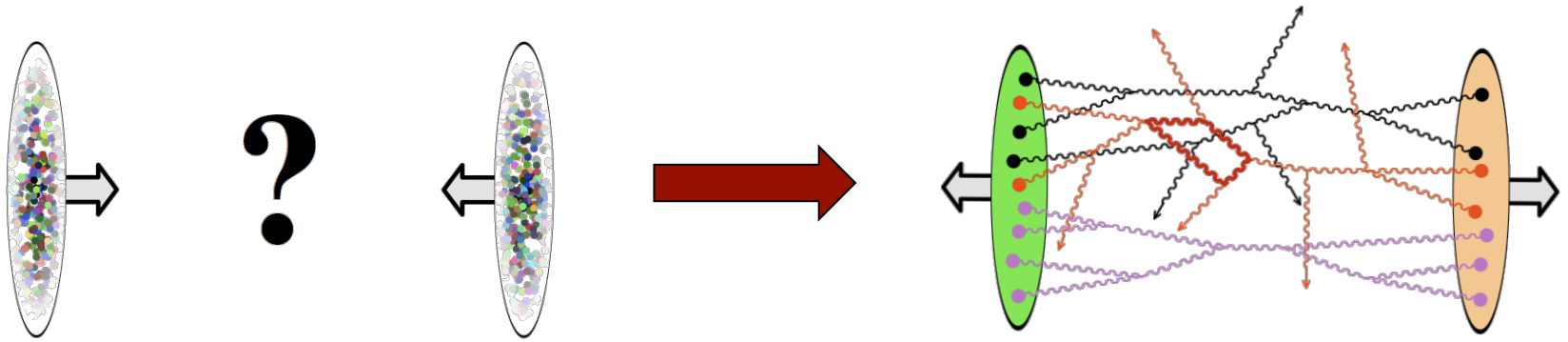
Standard model of HI Collisions



Outstanding questions: How does the high energy partonic structure of fluctuations generate early onset of flow?
What are the mechanisms for thermalization?
What is the origin of the Chiral Magnetic Effect?

Kowalski,Lappi,Venugopalan PRL (2008)

Early time dynamics in HI collisions



❖ First principles formalism *now available for detailed 3+1-D numerical simulations* includes: a) all leading multi-parton correlations in nuclear wavefunctions

b) all multiple scattering effects before and after collision

c) all order leading unstable quantum corrections after collision

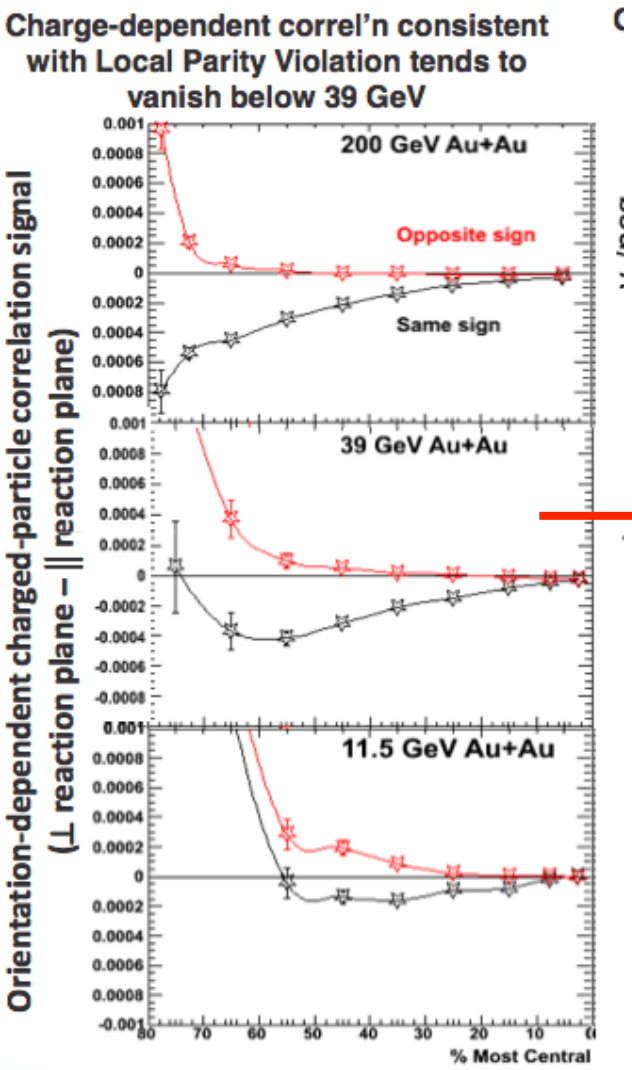
Dusling,Gelis,Venugopalan, arXiv:1106.3927

❖ Match on to novel transport regime – with superfluid like properties: important clues about nature of isotropization and thermalization

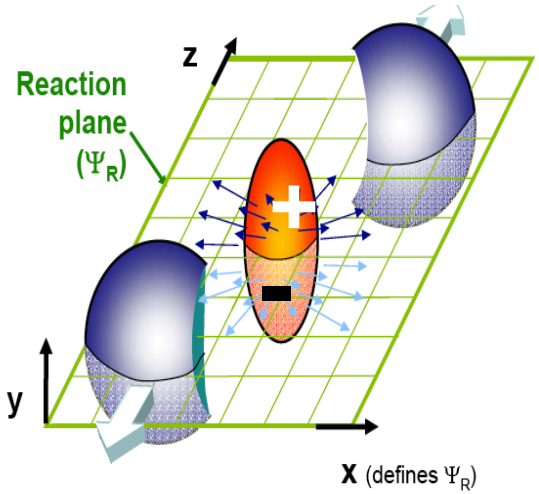
Blaizot,Gelis,Liao,McLerran,Venugopalan, in preparation

DM8,
DM9,
DM12
DM13

Chiral magnetic effect & local CP violation



Prediction: D. Kharzeev, L. McLerran, H. Warringa, Nucl. Phys. A803 (2008)227



Remarkable pattern at RHIC-onset of deconfinement ?

Effect also now seen at the LHC

Several lattice studies of CME

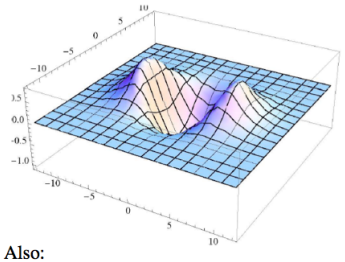
DM11

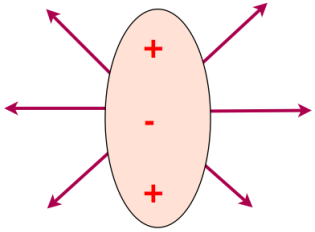
Prediction and observations widely reported in the press (April 2010 BNL press release) (NY Times,…)

Chiral magnetic effect & local CP violation

Recent developments

1) Electric quadrupole moment of QGP

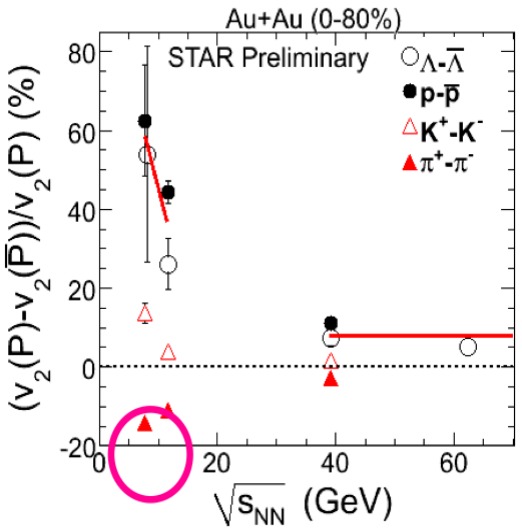




Also:
relevant for charge correlations!
(RHIC vs LHC)

Y. Burnier, D. Kharzeev, J. Liao, H-U. Yee, arXiv:1103.1307

Elliptic flow of positive pions should be smaller than that of negative ones (always, not a fluctuation!)



B.Mohanty [STAR] Quark Matter 2011

2) Chiral MagnetoHydrodynamics

Hydrodynamics with anomalies in the presence of external E-M fields

D. Kharzeev,H-U. Yee, arXiv:1105.6360
D. Kharzeev, H-U. Yee, PRD83 (2011) 085007

CMW: electric charge separation induced by topological transitions in external B field
CSE: chiral charge separation along external B field at finite baryon density

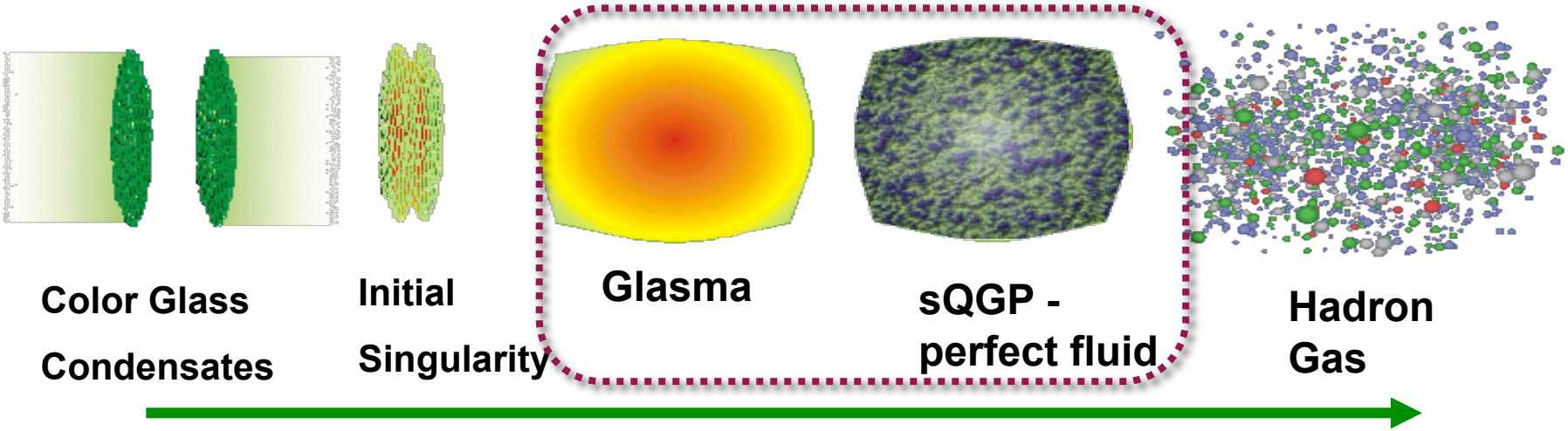
DM9, DM11

3) Vorticity induced coupled flow of CMW and CSE

Positive correlation of baryon # and electric charge: Λ π+ corr. ?

D. Kharzeev, D. Son, PRL106 (2011) 062301

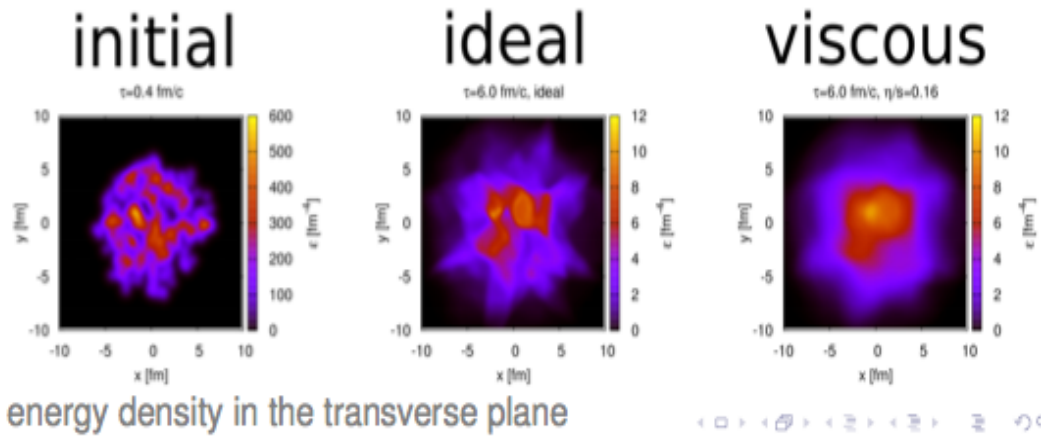
From Glasma to Plasma



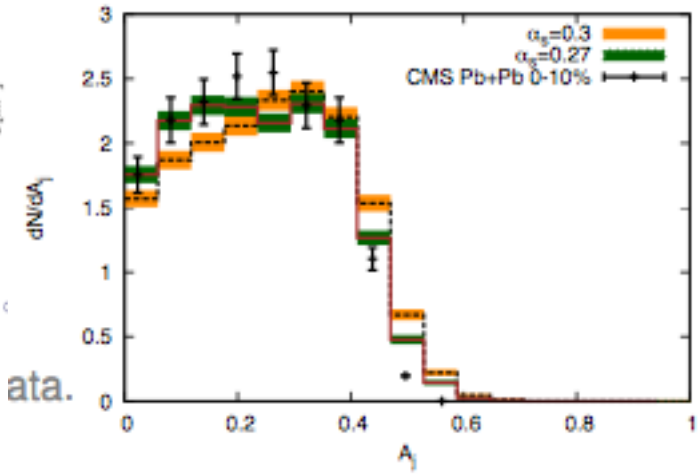
- Dynamics of the sQGP: 3+1-D event-by-event viscous hydrodynamics
- Properties of the sQGP: How does one compute properties of the strongly coupled fluid ?
- Hard probes of the sQGP: Jets, quarkonia

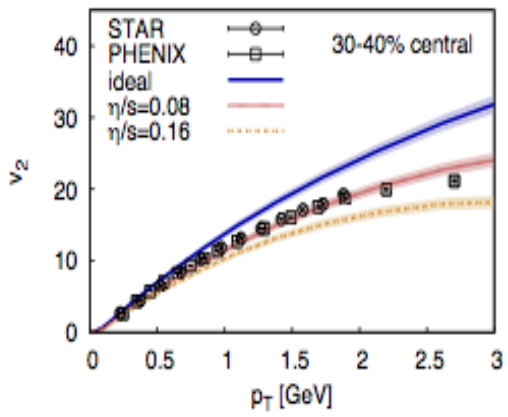
3+1-D event-by-event viscous hydro

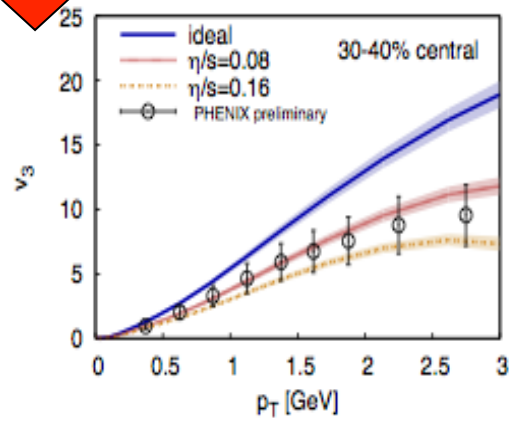
B. Schenke,S. Jeon,C.Gale, PRL106,042301 (2011)
B. Schenke,S.Jeon,C.Gale, arXiv:1102.0575



CMS di-jet asymmetry







MUSIC: 3+1-D viscous hydro code

MARTINI: Jet-medium interaction code Including 3+1 viscous hydro+ full jet reconstruction

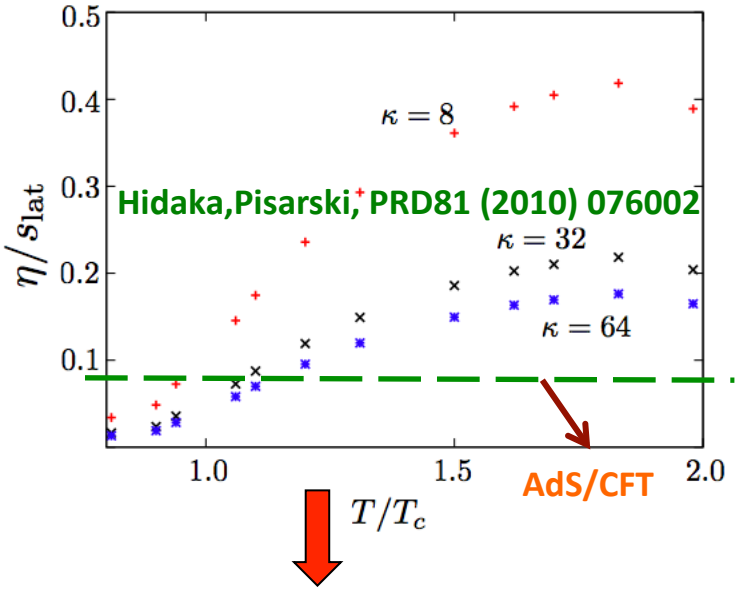
B. Schenke, S. Jeon, C. Gale, PRC83, 044907 (2011
C. Young,B.Schenke,S.Jeon,C.Gale, arXiv:1103.5769

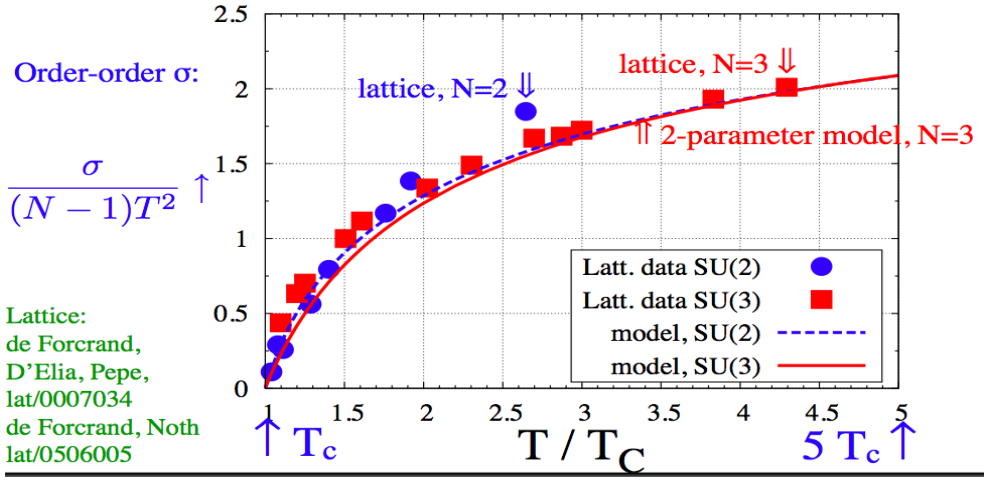
DM9,
DM10
DM12

Properties of the sQGP

- **Strongly correlated system: what are the degrees of freedom and dynamics?**

Two scenarios: a) semi-QGP (Pisarski et al., 2007--) EFT of Polyakov Loops





Use finite T lattice data to constrain parameters:
work in progress in this framework
To compute:

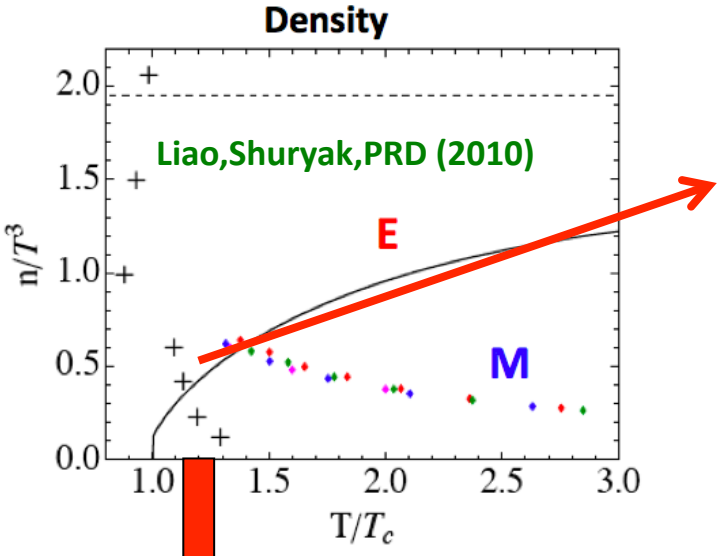
i) **Energy loss**
ii) **Di-lepton production**
iii) **Quarkonium dissociation**

DM9, DM10, DM12, DM13

Properties of the sQGP

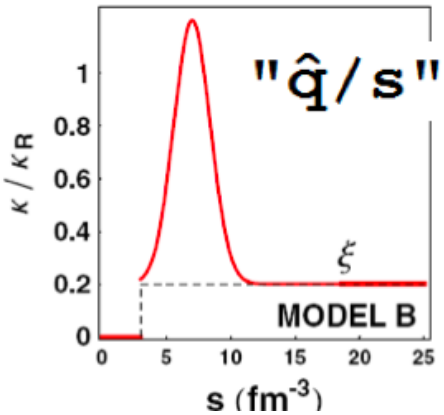
- **Strongly correlated system: what are the degrees of freedom and dynamics?**

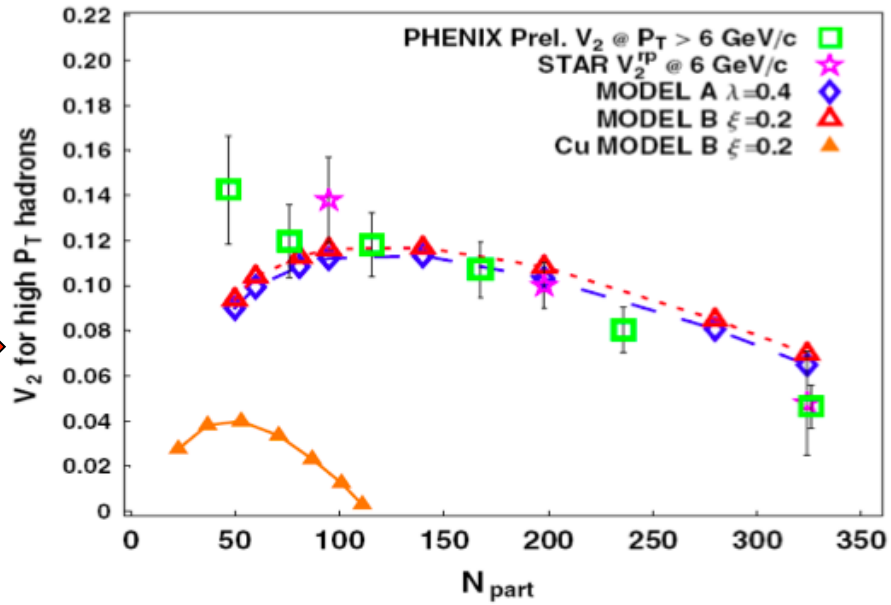
Two scenarios: b) Condensate of chromo-magnetic monopoles (Liao, Shuryak)



η/s minimal when
Density of elec. charges
≈ magnetic. charges

DM9,
DM10,
DM12,
DM13





Jet reconstruction algorithms

CMS It. Cone → anti-k_t (√ fast, √ safe) [M.Cacciari, G.Salam, G.Soyez, 08]

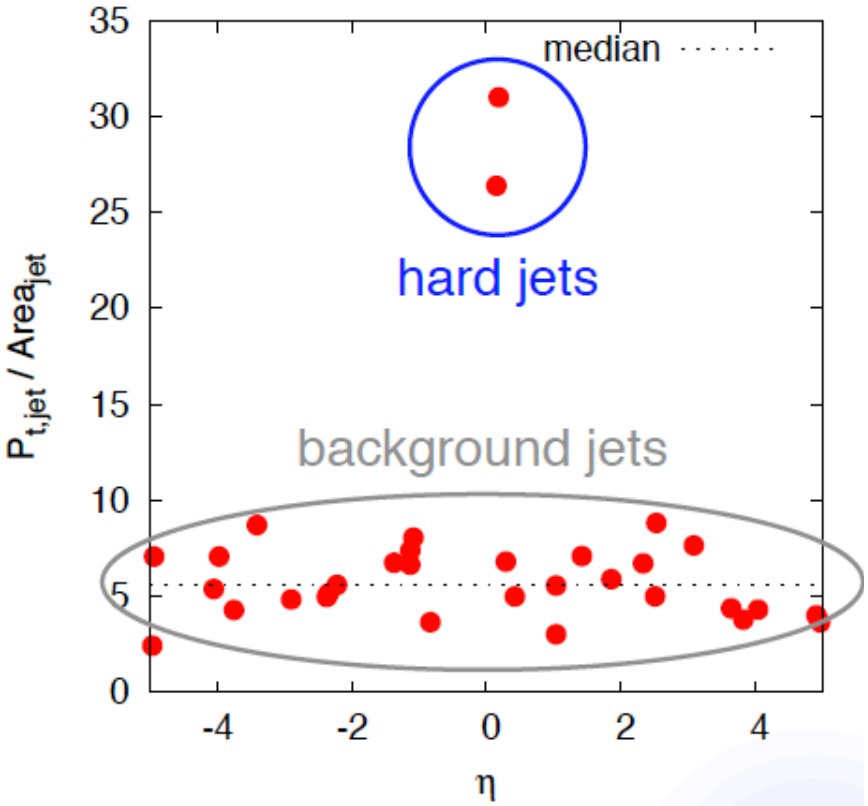
CDF/D0 Cone, ATLAS Cone → SISCone (√ fast, √ safe) [G.Salam, G.Soyez, 07]

Physics impact:

take full benefit of the ~ 100 M$ invested to compute pQCD process

Comments:

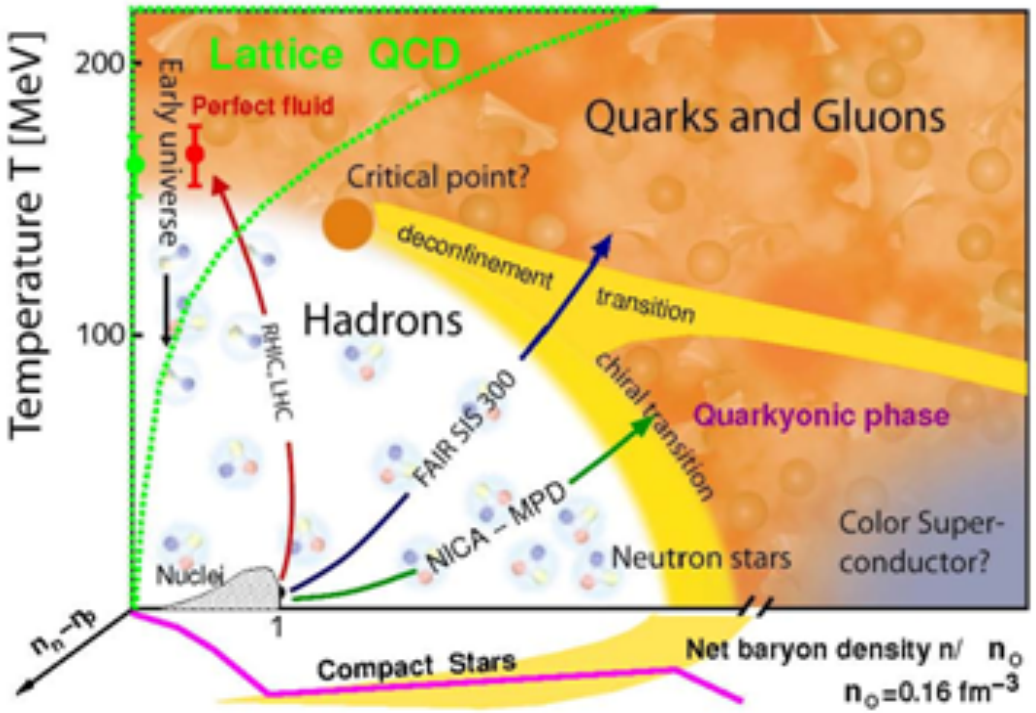
- anti-k_t adopted as default by ATLAS and CMS, used by STAR
- implemented in FastJet: the standard interface for jet algorithms
  [M.Cacciari, G.Salam, G.Soyez, www.fastjet.fr]



Major impact on jet studies at RHIC

QCD at finite Baryon density

Phases of cold, dense quarks at large Nc,
L. McLerran, R. D. Pisarski, NPA796 (2007)



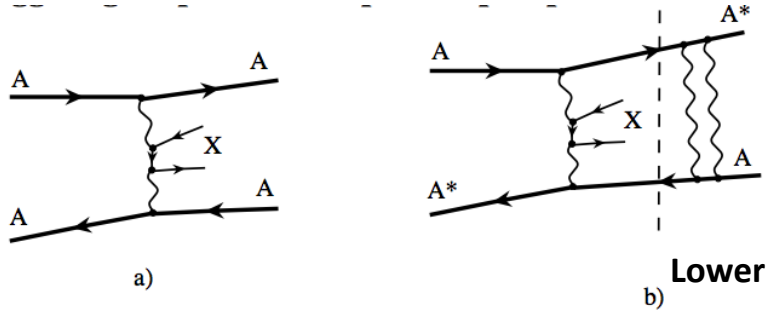
New idea: Possible novel phase of confined excitations of quark matter

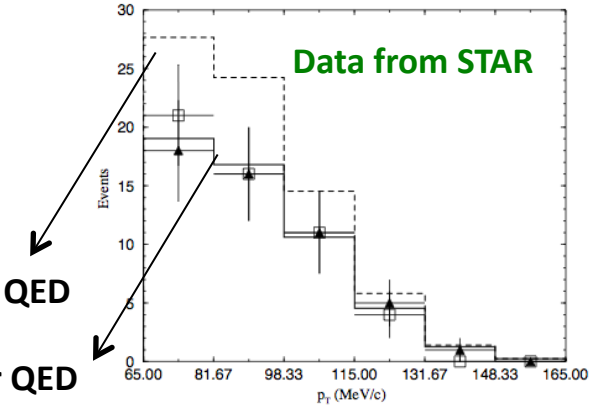
Kojo,Pisarski,Tsvelik, PRD82 (2010) 074015
Hidaka,Kojo,Mclerran,Pisarski, NPA852 (2011) 155
Kojo,Hidaka,McLerran,Pisarski, NPA843 (2010) 37

Andronic…Pisarski,McLerran, et al. NPA837 (2010) 65 : **possible phenomenological evidence for a triple point of Hadronic,QGP and Quarkyonic matter**

Ultra-peripheral heavy ion collisions

a) without and b) with nuclear breakup





Lower order QED

Higher order QED

A.J. Baltz, PRL100 (2008)062302

Higher order QED calculations consistent with higher m_{e+e-} data

Baltz,Nystrand,PRC82 (2010) 027901\
Baltz, PRC80 (2010) 034901

Production of quark-antiquark pairs in 2-photon interactions

Baltz,Gorbunov,Klein,Nystrand, PRC80 (2009) 044902

Two-photon production with 2.76 TeV/N Gold beams at LHC

Meson	J^{PC}	$\Gamma_{\gamma\gamma}$(keV)	overall	XnXn	1n1n
		(keV)	σ [mb]	σ [μb]	σ [μb]
η	0^{-+}	0.510±0.026	18.8	337	21.6
η'	0^{-+}	4.30±0.15	21.9	469	30.3
$f_2(1270)$	2^{++}	2.60±0.24	23.4	562	35.7
$f_2'(1525)$	2^{++}	0.081±0.009	0.38	9.7	0.62
η_c	0^{-+}	7.2±0.7±2.0	0.57	19.3	1.2
$\mu^+\mu^-$			2,017	33,084	2,128
$\tau^+\tau^-$			0.55	22.8	1.4

Nuclear structure

A. Gal,J. Millener, PLB701 (2011) 342

Shell model predictions for ΛΛ hypernuclei

$$B^{\rm SM}_{\Lambda\Lambda}({}^{\rm A}_{\Lambda\Lambda}{\rm Z}) = 2\overline{B}_{\Lambda}({}^{\rm A-1}_{\Lambda}{\rm Z}) + < V_{\Lambda\Lambda} >_{\rm SM}$$

Table 1: Comparison between $B^{\rm exp}_{\Lambda\Lambda}$ from KEK-E176,E373 and $B^{\rm SM}_{\Lambda\Lambda}({}^{\rm A}_{\Lambda\Lambda}{\rm Z})$ predictions [SM stands for shell model and CM for cluster model]. All values are in MeV. An asterisk refers to different interpretations of the same emulsion event.

${}^{\rm A}_{\Lambda\Lambda}{\rm Z}$	$\overline{B}_{\Lambda}({}^{\rm A-1}_{\Lambda}{\rm Z})$	$B^{\rm SM}_{\Lambda\Lambda}({}^{\rm A}_{\Lambda\Lambda}{\rm Z})$	$B^{\rm exp}_{\Lambda\Lambda}({}^{\rm A}_{\Lambda\Lambda}{\rm Z})$	$B^{\rm CM}_{\Lambda\Lambda}({}^{\rm A}_{\Lambda\Lambda}{\rm Z})$
${}^{6}_{\Lambda\Lambda}$He	3.12 ± 0.02	6.91 ± 0.16	6.91 ± 0.16	6.91
${}^{10}_{\Lambda\Lambda}$Be	6.71 ± 0.04	14.97 ± 0.22	14.94 ± 0.13	14.74
${}^{11}_{\Lambda\Lambda}$Be	8.86 ± 0.11	18.40 ± 0.28	17.53 ± 0.71 *	18.23
			20.83 ± 1.27 *	
${}^{12}_{\Lambda\Lambda}$Be	10.02 ± 0.05	20.72 ± 0.20	22.48 ± 1.21 *	–
${}^{12}_{\Lambda\Lambda}$B	10.09 ± 0.05	20.85 ± 0.20	20.60 ± 0.74 *	–
${}^{13}_{\Lambda\Lambda}$B	11.27 ± 0.06	23.21 ± 0.21	23.3 ± 0.7 *	–

Synergistic activities: EIC

(see T. Ullrich presentation)

i) Qiu, Stratmann, Venugopalan actively work with BNL taskforce on EIC studies

ii) Qiu and Venugopalan have LDRD awards to explore important aspects of EIC physics; M. Stratmann has a pending LDRD application on EIC

iii) Venugopalan was a co-organizer of INT program on EIC and co-editor editor of the (+500 page) INT report on the Science Case for EIC (to appear July 2011)

Qiu is co-editor of EIC white-paper (to appear early 2012)

Synergistic activities: RHIC II theory initiative

- **Initiative of BNL Lattice and Nuclear theory groups (co-ordinator: P. Petreczky)**

- **Goal: address problems of common interest to theorists and experimentalists vital to key aspects of RHIC physics program**

- **Topical workshops, focused visitor program – partial support from BSA, RBRC and limited group resources**

Webpage: http://quark.phy.bnl.gov/www/rhic2/rhic2.html

Recent summer program: Quarkonium production in elementary & heavy ion collisions (June 6-18, 2011) Organizers: A. Dumitru, C. Lourenco, P. Petreczky, J. Qiu, L. Ruan

Upcoming workshops: i) Fluctuations and correlations in RHIC low energy runs (10/3-5)
ii) Thermal photons and di-leptons (10/21-23, 2011)

RBRC Theory group

Three Main Activities

- Proton Spin structure
  - Polarized Parton Distribution Function
  - Transverse Spin Physics
- High density QCD matter
  - Quark Gluon Plasma
  - Color Glass condensate
- Lattice QCD
  - 1st principle calculations
  - QCD thermodynamics

Founding Director:
T.D. Lee

Director:
N. Samios

Head, Theory group:
L. McLerran

Deputy head:
A. Baltz

Theory group has close Cooperation with BNL NP Theory and Lattice Group

Lattice QCD group use QCDOC 10TFLOP computer

New QCDCQ (~600TFLOPS peak) will be installed soon

Scientific Personnel (Theory)

Fellows:

Denes Molnar	Purdue University (2010)
Kirill Tuchin	Iowa State University (2010)
Feng Yuan	Lawrence Berkley National Laboratory
Rainer Fries	Texas A&M University (2011)
Cecilia Lunardini	Arizona State University
Derek Teaney	Stony Brook University (SUNY)
Adrian Dumitru	Baruch College (CUNY)
Anna Stasto	Pennsylvania State University
Yasumichi Aoki	Brookhaven National Laboratory (2011)
Taku Izubuchi	Brookhaven National Laboratory
Shigemi Ohta	Guest

Post docs:

Zhongbo Kang; Toru Kojo (SPD); Christoph Lehner (FPD); Eigo Shintani

RIKEN-BNL Theoretical Physics Fellows

Graduates

T. Blum, Tenured, U of Connecticut
D. Bodeker, Tenured C4, Bielefeld
D. Kharzeev , Tenured BNL
D. Rishke, Tenured C-4 Frankfurt
D. Son, Tenured U of Washington
R. Venugopalan, Tenured BNL
T. Wettig, Tenured C-3 Regensburg
M. Stephanov Tenured U of Ill, Chicago
U. Van Kolck, Tenured U of Arizona
T. Schaefer, Tenured U of N. Carolina
A. Kusenko, Tenured UCLA
W. Vogelsang, Tenured at BNL
S. Bass, Tenured at Duke
T. K. Iida Tenured at Koichi U,
U. Wiedemann, Perm. Staff, CERN
S. Sasaki, Assoc. Prof. U of Tokyo
S. Jeon, Tenured at McGill
Chris Dawson*, Asst. Prof. Virginia

Former Japanese Fellows and post-docs in permanent positions

Kenji Fukushima Yukawa Inst. Asst. Professor

K. Iida Tenured Koichi U.

Hiro Fuji Ass. Professor U of Tokyo

S. Sasaki Assoc Prof. U of Tokyo

Tetsu Hirano Asst. Prof. U of Tokyo

Masakiyo Kitazawa Asst. Prof. Osaka U.

Yoshi Hatta Asst. Prof. Tsukuba U.

Y. Nara, Asst. Prof. Akita Intl. U.

Taku Izubuchi, Kanazawa U -> BNL

Kazu Itukura, KEK

Workshops:

Spin and Pert. QCD 39

Lattice and Computing 11

Quark Gluon Plasma 8

High Energy QCD 2

Jets and Hard Processes at RHIC 5

Flow, Hydrodynamics and Event Simulation 5

Hadron Physics and QCD 4

Color Glass Condensate 3

New Discoveries at RHIC 1

Recent workshops

- Progress in high-p_t physics at RHIC , March 17-19, 2010 – Vol. 95
- P- and CP-odd effects in Hot and Dense Matter , April 26-30, 2010 – Vol. 96
- EIC Meeting at Stony Brook , January 10-12, 2010
- Saturation, the Color Glass Condensate and Glasma: What have we learned from RHIC? May 10-12, 2010 – Vol. 98
- The Physics of W and Z Bosons June 24-25, 2010 – Vol. 99
- BNL Summer Program on Nuclear Spin Physics July 14-27, 2010 – Vol. 100

Publications

Theory - 42

Experiment - 29

RBRC Request for 6 Year Renewal

Total Number of RBRC Fellows and Post Docs

Past and Present: approx. 100

63 Theory 37 Experimental

Japanese: 24 Theory; 21 Experimental = 45

Past Fellows

20 Theory → 19 Tenure 1 Other Fields

12 Experimental → 8 Tenure 2 Other Fields 2 Not yet

Success Ratio: 27/30 = 90%

Past Post Docs

26 Theory → 10 Tenure 16 Not yet

13 Experimental → 7 Tenure 6 Not yet

Total Tenure to date: 27+17 = 44

International - Tenure

Theory:	**10 U.S.**	**10 Japan**	**9 Western Europe**
Experimental:	**4 U.S.**	**11 Japan**	**---------**

Summary

- BNL Nuclear theory is a World leader in high energy nuclear physics
- Vigorous research program aimed at understanding fundamental structure of matter and achieving RHIC goals
- Synergy with research done by experimental groups, RBRC, Lattice Gauge Theory, High Energy and Condensed Matter groups
- Initiatives to solidify science case for RHIC II and EIC